



Synoptic Analysis of the New York March 1888 Blizzard

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Abstract

The meteorological circumstances that led to the Blizzard of March 1888 that hit New York are analysed in Version 2 of the “Twentieth Century Reanalysis” (20CR). The potential of this data set for studying historical extreme events has not yet been fully explored. A detailed analysis of 20CR data alongside other data sources (including historical instrumental data and weather maps) for historical extremes such as the March 1888 blizzard may give insights into the limitations of 20CR. We find that 20CR reproduces the circulation pattern as well as the temperature development very well. Regarding the absolute values of variables such as snow fall or minimum and maximum surface pressure, there is an underestimation of the observed extremes, which may be due to the low spatial resolution of 20CR and the fact that only the ensemble mean is considered. Despite this drawback, the dataset allows us to gain new information due to its complete spatial and temporal coverage.

1. Introduction

On 12 March 1888 a tremendous blizzard turned the region of New England in the North East of the United States into an emergency area (Fig. 1). Within one day, temperatures fell from 5.5 °C to -10 °C (Kocin, 1983). At the same time, a cyclone over the western Atlantic Ocean just off the coast of New York steered very moist air masses towards New England, which lead to substantial snowfall (Kocin, 1988). Within three days from 11 to 14 March up to 125 cm of new snow were measured at meteorological stations around New York City (Kocin, 1988). The strong wind created snow drifts up to 7.5 metres high.

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Figure 1. 45th Street and Grand Central Depot, New York, on March 12 1888 (National Oceanic and Atmospheric Administration/Department of Commerce, NOAA's National Weather Service (NWS) Collection).

Electricity, telegraph, and telephone lines were broken and railways and steamships were stuck. Over 400 people died, 200 of them in New York (Hughes, 1976). The Blizzard of 1888 is still a remembered extreme event and is seen as the most disastrous blizzard that ever hit New York.

With the newly available 20CR – as compared to observations - we have the opportunity to study all relevant variables in a spatially complete, 3-dimensional grid. The aim of this paper is to analyse the synoptic development by using 20CR reanalysis data. A comparison to the results from previous studies is done to gain knowledge about the strengths and weaknesses of the new reanalysis dataset.

2. Data and Methods

The study is based on the “Twentieth Century Reanalysis” version 2 data (20CR). This data set is available for the period from 1871 to 2010 (Compo et al., 2011). It is based on the assimilation of observational surface and sea-level pressure (SLP) data into the NCEP/CFS atmospheric model using a variant of the Ensemble Kalman Filter. The model is run at T62 spectral truncation (corresponding to a horizontal resolution of $2^\circ \times 2^\circ$) and 28 levels in the vertical, forced with monthly sea-surface temperatures and sea ice concentrations (Rayner et al., 2003). The data set has a six-hourly temporal resolution, additionally, three-hourly forecast are provided for several variables (Compo et al., 2011). Note that 20CR is an ensemble product, with 56 equally likely members. In the following, however, we focus only on the ensemble mean.

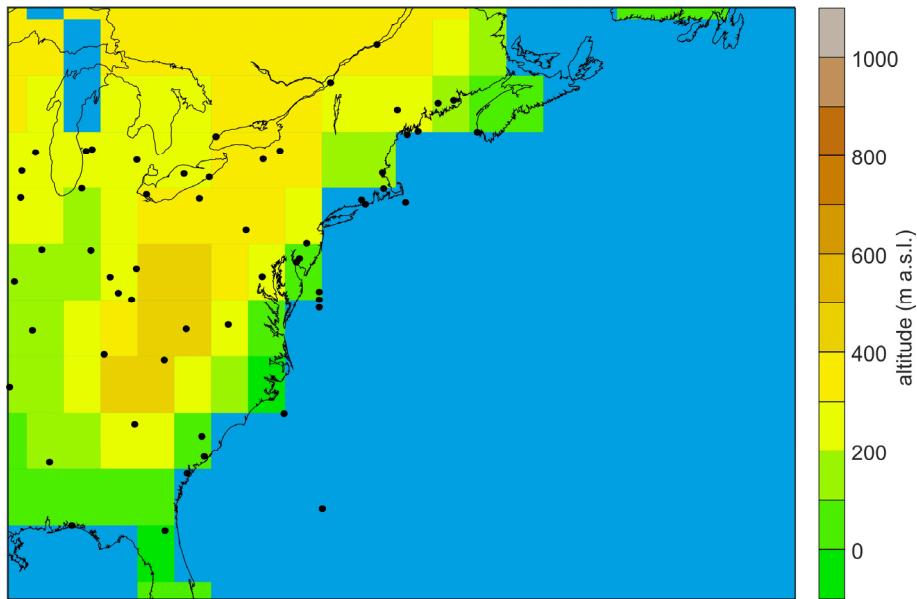


Figure 2. Map showing the surface and sea-level pressure measurements assimilated into 20CR on 12 March 1888, 6 UTC. Colours indicate the orography in 20CR and the land-sea mask as depicted in the Gaussian grid (192x94 cells).

Figure 2 shows the locations of pressure data that were assimilated into 20CR for the analysis on 12 March 1888, 6 UTC. Colours indicate the orography as well as the land-sea mask. The number of observations is rather low compared with later periods. We investigate the period from 10 to 14 March 1888, over the domain 22° - 50° N and 105° - 60° W. We use six-hourly SLP and 500 hPa geopotential height (GPH) fields, as well as three-hourly fields of 10 m wind, 2 m temperature, specific humidity, snow depth, and precipitation rate.

To assess whether the 20CR data set is able to reproduce the extraordinary high snowfall during the event, we sum the precipitation rates over four days and calculate the difference between snow depth on 14 March, 0 UTC and 10 March, 0 UTC. For validation purposes we use historical station data recorded in the monthly weather review (United States Signal Service, 1888) and additionally the surface pressure maps and data given by Kocin (1988).

3. Results

3.1. Surface Analysis

10 March 1888

A mid-tropospheric ridge was located over the eastern U.S., associated with a surface high over the north-eastern U.S. Between its western edge and the Mississippi, southerly surface winds prevailed, while northerly flow was present in the northern half of the US west of the Mississippi, with south-easterly winds over the Gulf of Mexico. Low-level winds converged over Texas and Oklahoma. Another high-pressure centre was located over the Rocky Mountains states; low pressure was present over the western Gulf and southern Texas (Fig. 3, top left panel).

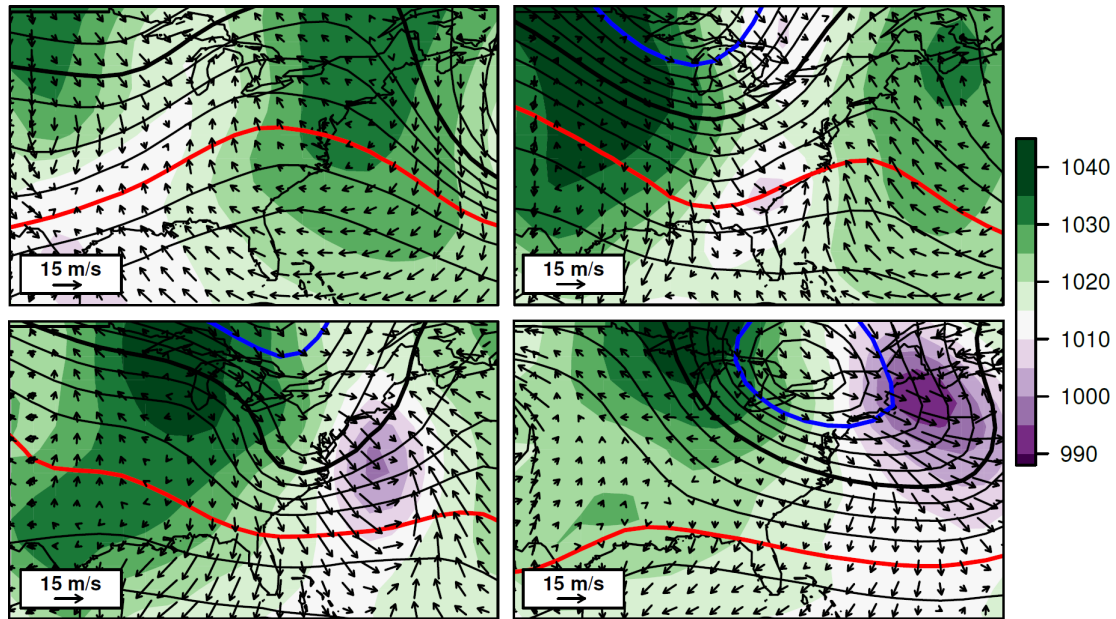


Figure 3. Mean sea-level pressure (hPa, shaded), 500h Pa GPH (black contours in steps of 50 gpm, the red line denotes 5500 gpm) and 10 m wind vectors. Top left: 10 March 1888, 12 UTC; top right: 11 March 1888, 12 UTC; bottom left: 12 March 1888, 12 UTC, bottom right: 13 March 1888, 12 UTC (all data are from 20CR).

11 March 1888

On 11 March a trough had formed reaching from the Great Lakes southwards to Alabama (Fig. 3, top right panel). Two low-pressure centres were located above Georgia and South Carolina and north of Lake Huron. The western high-pressure area had strengthened, covering the entire Western U.S. The eastern high-pressure area had moved eastward to Nova Scotia. Highest wind speeds of 18 m/s were located over the Atlantic at the eastern edge of the low-pressure area over South Carolina. Rain was widespread along the central Eastern U.S. Coast, falling at Buffalo, N.Y., Pittsburgh, P.A., and Washington, D.C. (Kocin, 1983).

12 March 1888

The western high-pressure area, associated with cold air intrusion from Canada (Fig. 4, left panel), was situated over the western Great Lakes (Fig. 3, bottom left panel). The surface low, located about 300 km east-southeast of Assateague Island (in front of Chesapeake Bay) over the Atlantic, had deepened to a central pressure of 999 hPa, with a rate of about 10 hPa per 24 hours. This process was strongly favoured by the position of the surface low under the divergent upper winds in front of the approaching trough to the west. At the same time, the northern low-pressure centre weakened due to the advection of cold air that moved in the direction of New York (Fig 4, left panel). At this time, heavy snowfalls were reported in the north-eastern U.S. and particularly in New York City (Kocin, 1983).

The cyclone carried warm moist air at its eastern to north-eastern edge to the northeast of the U.S., where the warm air masses encountered the anomalously cold air masses from Canada (Fig. 4). Together, this led to the heavy snowfall events (Kocin, 1983).

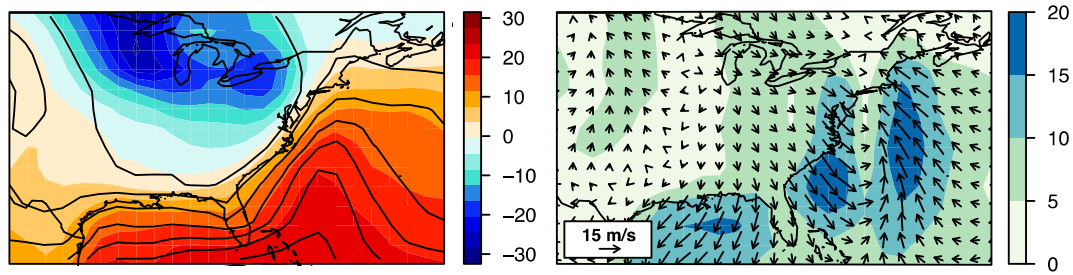


Figure 4. The meteorological situation on 12 March 1888, 12 UTC. Left: Surface temperature ($^{\circ}\text{C}$) and lines of constant specific humidity (solid black lines, from 2 g/kg to 14 g/kg in steps of 2 g/kg) (g/kg). Right: 10 m wind speed (m/s) and wind direction, the colours show wind speed (all data from 20CR).

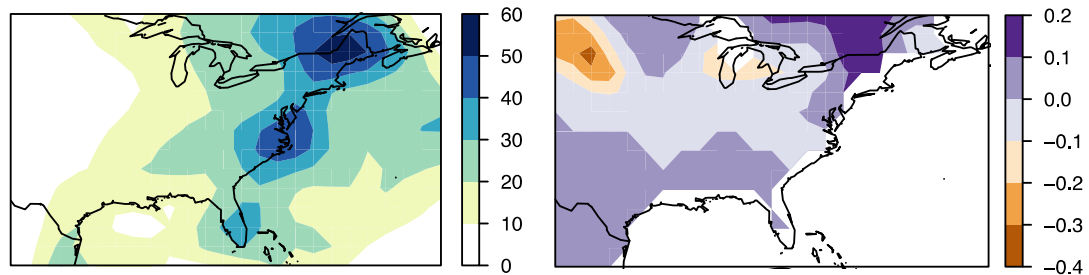


Figure 5. Left: Total precipitation (mm) from 10 March 1888, 0 UTC to 14 March 1888, 0 UTC. Right: Change in snow depth (m) from 10 March 1888, 0 UTC to 14 March 1888, 0 UTC (all data from 20CR).

13 March 1888

On 13 March the high pressure area over the western Great Lakes remained almost stationary while the cyclone deepened further and moved north-eastwards towards the coast of Maine. The central pressure of the cyclone at this time was 991 hPa. The effects for the north-eastern U.S. were unchanged, with heavy snowfalls and low air temperatures down to -20°C (Fig. 4, left panel, Kocin, 1983). At the southern edge of the cyclone strong (up to 20 m/s) north-westerly winds were present while the rest of the U.S. experienced calm conditions.

3.2. Temperature and wind speed

Figure 4 (left panel) illustrates the strong air temperature gradient along the coast of the north-eastern U.S. on 12 March, 12 UTC. This gradient of 36 K over a distance of around 500 km was essential for high snowfalls. The wind speed was highest (19 m/s) southwest and southeast of the cyclone centre (Fig. 4, right panel). There was a convergence of warm and wet air masses from the Atlantic and cold air masses from the northwest.

3.3. Total precipitation and change in snow depth

The accumulated precipitation from 10 March, 0 UTC to 14 March, 0 UTC (Fig 5, left panel) shows two maxima; one over the state of Maine and the other one at the coast of Virginia and New Jersey. The peak values in 20CR were around 50 mm over the four days. The change of the snow depth was highest over the state of New York (Fig. 5) in the reanalysis. There were large areas at the coast for which no snow depth information is available because the corresponding cells were over sea in 20CR (sea land-sea mask in Fig. 2). As no snow can be accumulated in the ocean grid-cells, there is no data in those cells.

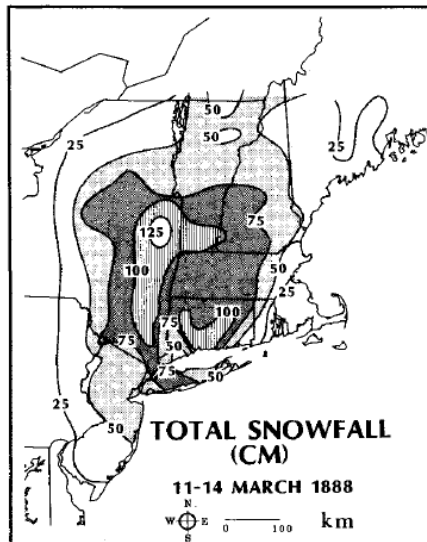


Figure 6. Snow fall [cm] from 11 to 14 March, 1888, from historical measurements (source: Kocin, 1988).

4. Discussion

The 20CR data set provides a new opportunity to depict and assess the meteorological development of the blizzard of 1888. Comparing the representation of the meteorological conditions in 20CR to an analysis by Kocin (1988) from surface weather observations reveals several differences. The minimum surface pressure of the low-pressure system on 13 March, 12 UTC, yields 990.7 hPa (with a standard deviation of the ensemble spread of 2 hPa at that location and time), whereas Kocin (1988) reports a depth of 988 hPa. Six hours earlier, on 13 March, 6 UTC, a minimum pressure of 989 hPa is found in 20 CR. Overall this shows that 20CR is close to Kocin's (1988) analysis.

Larger differences appear in the snow accumulation. According to Kocin (1988) the snowfall accumulation within three days yielded up to 125 cm. The maximum accumulated snow height in 20CR is 20 cm. However, the maximum accumulated precipitation over the four days is almost 50 mm including snow (in water equivalent) in 20CR. Assuming an average fresh snow density of 50-100 kg/m³ the snow accumulation is between 50 cm and 1 m. This is approximately equivalent to an average of the historical measurements shown on the map in Figure 6. A reason for the underestimation of snowfall in the 20CR ensemble mean could be that the grid-cells are too large to detect small scale maxima. Furthermore, the snow depth ensemble spread over the north-eastern U.S. for March 10 and March 14 is up to 25 cm (not shown), revealing large differences within the single ensemble members.

The comparison of the instrumentally measured 2 m temperatures in New York City and the 2 m temperatures from the nearest grid point in the 20CR reanalysis during the blizzard event are shown in Figure 7. The temperature evolution over time shows the same general characteristics, with mostly positive temperatures before and a rapid cooling after 12 March, 21 UTC. However, until 11 March, 6 UTC temperatures diverge up to 5 K. From 12 March, 0 UTC onwards both data sets show a similar dramatic cooling of about 20 K. In the 20CR data the cooling is briefly interrupted by a short warming period before further cooling sets in. Note, that the grid point is situated 90 km northwest of New York. The exact temperature distinguishes snow from rain conditions, which may contribute to the differences in snow depth change.

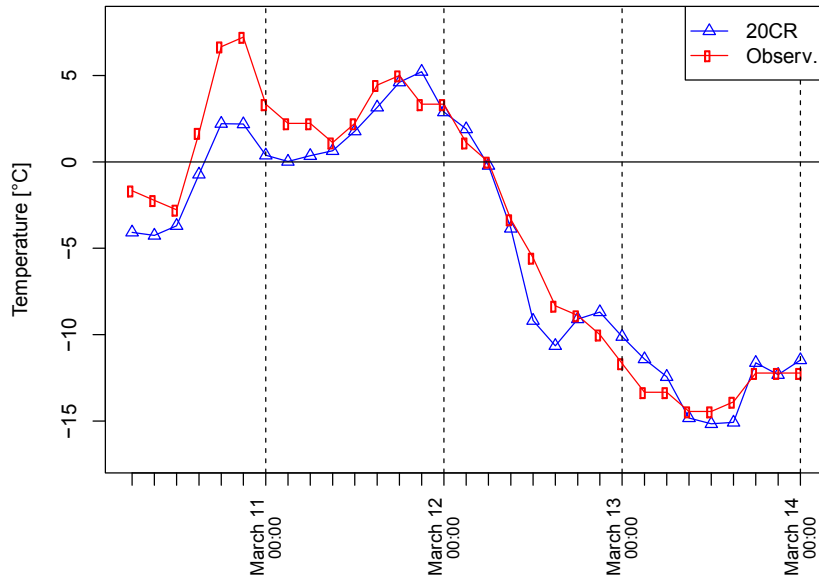


Figure 7. Temperatures (°C) from 10 March 1888, 6 UTC to 14 March 1888, 0 UTC in 3 hour steps. Red: observed records from the meteorological observatory at Central Park, New York City (Kocin, 1983). Blue: 20CR data of the nearest grid point (285.000° E, 40.952° N).

5. Conclusions

The circulation characteristics during the evolution of the blizzard of 1888 are well depicted in the 20CR data set when compared to historical weather charts (Kocin, 1988). Only slight differences appear in the timing and the magnitude of the low pressure system. Snow depths are less well represented in the ensemble mean of the 20CR data set, possibly due to the low spatial resolution and the coarse representation of the topography in 20CR. There is a large spread in snow depth of the ensemble members (up to 25 cm) in the north-eastern U.S. during the event. Furthermore, there is no snow accumulation in ocean grid cells, which also affects the coastal region around New York. Absolute surface temperature values and their temporal evolution during the event correspond well with observations.

In all, the meso-scale meteorological conditions of the blizzard 1888 are well depicted in Version 2 of the Twentieth Century Reanalysis data set. Features with high spatial heterogeneity, such as snow depth, are associated with large uncertainties (*i.e.*, large ensemble spread) and reveal larger differences when compared to historical observations.

Acknowledgments

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